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AN SEM ANALYSIS OF BEARING FAILURE DUE TO ELECTRICAL ARCING

by

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National Aeronautical Establishment

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AN SEM ANALYSIS OF BEARING FAILURE DUE TO ELECTRICAL ARCING

ANALYSE PAR MICROSCOPIE ÉLECTRONIQUE À BALAYAGE DE L'ENDOMMAGEMENT D'UN ROULEMENT À BILLES À LA SUITE DE DÉCHARGES ÉLECTRIQUES INTERNES

by/par

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National Aeronautical Establishment

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SUMMARY

Failure of a cam clutch after some 2,000 hours of operation was found to be due to bearing failure. When examined in the scanning electron microscope, evidence of molten metal in the form of craters or pools, and of minute globules of metal was found on the balls and races of the bearings. This suggested that electrical arcing between the balls and the races had occurred, and this was considered to be the primary cause of subsequent fatigue and other mechanical damage to these components.

RÉSUMÉ

Une analyse par microscopie électronique à balayage a permis de démontrer que l'endommagement d'une came à embrayage après 2000 heures de fonctionnement, était attribuable en permier lieu à l'endommagement interne d'un roulement. Des traces de fusion métallique sous la forme de cratères ou dépressions et de minuscules goutelettes solidifiées de métal ont été mises en évidence à la surface des billes de roulements et des voies de glissement par microscopie électronique à balayage. Cela suggère que des décharges électriques et crachements d'étincelles se sont produits entre les billes et les parois des voies de glissement en cours de service. On en a conclu que cet endommagement était la cause primaire de l'endommagement subséquent par fatigue et autres modes d'endommagement mécaniques subis par ces pièces.

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ILLUSTRATIONS

AN SEM ANALYSIS OF BEARING FAILURE DUE TO ELECTRICAL ARCING

Premature failure of rolling element bearings may be ascribed to such causes as inadequate lubrication, contamination by abrasive materials, incorrect loading conditions on installation or during operation, corrosive environments, and stray electric currents, or combinations of these parameters. In order to prevent recurrence of premature bearing failures it is essential to pinpoint accurately the primary cause of failure by identifying the predominant failure mechanisms so that appropriate remedial action can be taken. For this purpose the use of the scanning electron microscope (SEM) may frequently be most rewarding, as the following description of the failure analysis of a cam clutch illustrates.

Failure of the cam clutch, which was designed to lock positively to transmit torque in one direction of rotation, and to overrun (free-wheel) in the opposite direction, was indicated after a total of some 2000 operating hours. When rotated by hand, a certain roughness was noted, and metal particles were found in the clutch lubricant upon draining. Approximately 1/8 inch of axial movement of the outer race with respect to the inner race was noted, and complete seizure of the clutch occurred after the outer race had been rotated a number of turns by hand. Although the clutch was rated at a maximum torque of 27,000 in. lb. by the manufacturer, the working range was stated to be between 0 and 2,500 in. lb. The clutch unit was located immediately adjacent to an electric generator.

Visual examination of the two radial ball bearings after pressing them out from either end of the clutch indicated that the first bearing "A" was from outward appearances in a reasonably good state, with little axial movement possible between inner and outer rings. However, a degree of roughness was noted on rotation. Bearing "B" from the

opposite end of the clutch, an identical bearing to "A", exhibited gross movement possible between inner and outer rings, to the extent that complete failure of the bearing was indicated. The bearings were nominally 4 in. outside diameter, and each contained 16 balls of 0.375 in. (9.5 mm) diameter.

Removal of the balls from bearing "A" indicated a dark gray discolouration of the balls and the inner and outer races. Although, to a great extent the surfaces of the balls were relatively smooth and undamaged, all but two of the 16 balls exhibited one or more relatively large craters on their surfaces, ranging from 1 to 3 mm. in diameter, Figure 1. Where several craters were observed on one ball, they appeared in some instances to be circumferentially aligned on the surface, as shown in Figure 2. At higher levels of magnification of the SEM, globules or beads of what appeared to be previously molten metal were found in the craters on the surfaces of the balls from this bearing, Figure 3. Although some 43 craters were counted on the surfaces of 14 of the balls from this bearing, only three rather large cratered areas were observed on the outer race. Two of these were located some 11.0 mm apart, and measured approximately 3 and 4 mm in length. One of these is shown in Figure 4. A larger cratered area measuring some 4 by 7 mm was located diametrically opposite from the region of the other two craters in this outer race. The race in the inner ring of this bearing exhibited no comparable cratered areas.

The balls from bearing "B" were severely mutilated over their entire surface, Figures 5 and 6, and numerous sizable depressions on their surfaces exhibited interesting features when viewed at higher magnifications in the SEM. The first of these could be described as craters or perhaps more correctly as "pools" of molten metal that had solidified so rapidly that circumferential ripples had been "frozen" on the surfaces of the pools, Figure 7. Other features of

interest were small fracture surfaces with a series of coarsely spaced fatigue striations emanating from the edge of the pools, as illustrated in Figure 8. The direction of fatigue crack growth is indicated by the arrow in this figure. Since the edge of the pool appears to be the initiator of the minute fatigue crack, it would appear that the formation of the crater could be considered to be the primary damage, and that small areas of the surfaces of the balls had flaked off under the influence of cyclic stresses. Examination of such striated areas at higher magnifications revealed no evidence of finely spaced fatigue striations, so that it is concluded that only some 20 stress cycles were required to create the fatigue fracture surface (Figure 8) formed by the fatigue crack some 4.0 mm in length. Thus the fracture could be described as resulting from low cycle fatigue produced by relatively high levels of cyclic stress. Minute globules, such as that illustrated in Figure 8, found in the depressions on various balls from this bearing, indicate that microscopic melting of the metal had occurred in numerous locations on any given ball.

Both inner and outer races of bearing "B" show evidence of damage over their entire circumferences on one edge of the races, arrows Figure 9, as well as areas of major damage in the form of severe pitting in the races, Figure 10.

A metallographic section of a ball from bearing "B" indicated sub-surface cracking, Figure 11, resulting from abnormal localized surface stresses during rotation, due to coarse surface irregularities. Such sub-surface cracking likely corresponds to the formation of the low cycle fatigue fracture surfaces, as illustrated in Figure 8. Hardness measurements on the sectioned ball indicated values of 62Rc, which is apparently appropriate for steels used in the rolling elements in this type of bearing[1].

Since there was no evidence of damage or wear on the actual

clutch mechanism, it is concluded that the primary cause of failure of the component was bearing damage. Evidence of molten metal in the form of craters or pools, and minute globules of metal suggest strongly that electrical arcing between the balls and the races had occurred and that this was most likely the primary cause of subsequent mechanical damage to the surfaces of the balls and the races. Some of the craters appeared to have been formed by momentary welding together of the ball and race, with subsequent tearing apart of the minute weld joint as the balls rolled in the races.

Although the source of the electric currents flowing through the bearings could not be established, the proximity of the clutch to an electric generator might suggest leakage currents or induced currents. Alternatively, static discharges between the races and the balls may have been involved in the arcing.

Remedial action could involve the introduction of a conductive lubricant into the clutch, or some mechanical means of maintaining zero electrical potential between the inner and outer rings of the bearings. While bearing "A" shows evidence of few (43) relatively large discharges, the balls from bearing "B" bear evidence of numerous small discharges. Unfortunately, it could not be determined which of the two bearings was immediately adjacent to the generator, or whether proximity to the generator influenced the nature of the electrical discharges.

REFERENCE:

1. ASM Metals Handbook, Vol. 10, "Failure Analysis and Prevention", P. 417, American Society for Metals, Metals Park, Ohio, 44073.

FIG. 1: TYPICAL CRATER ON BALL FROM BEARING "A"

FIG. 2: CRATERS CIRCUMFERENTIALLY ALIGNED ON BALL, BEARING "A"

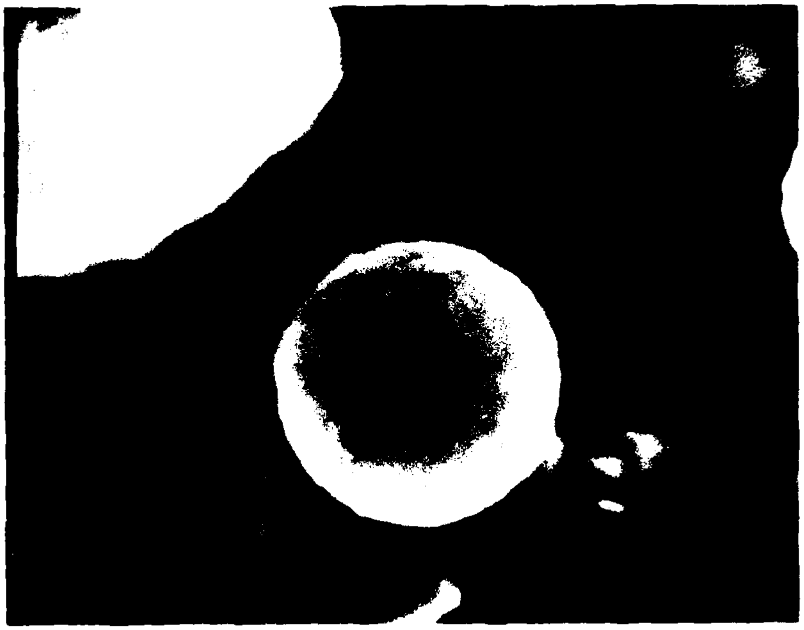


FIG. 3: GLOBULE OF MOLTEN METAL, BEARING "A"

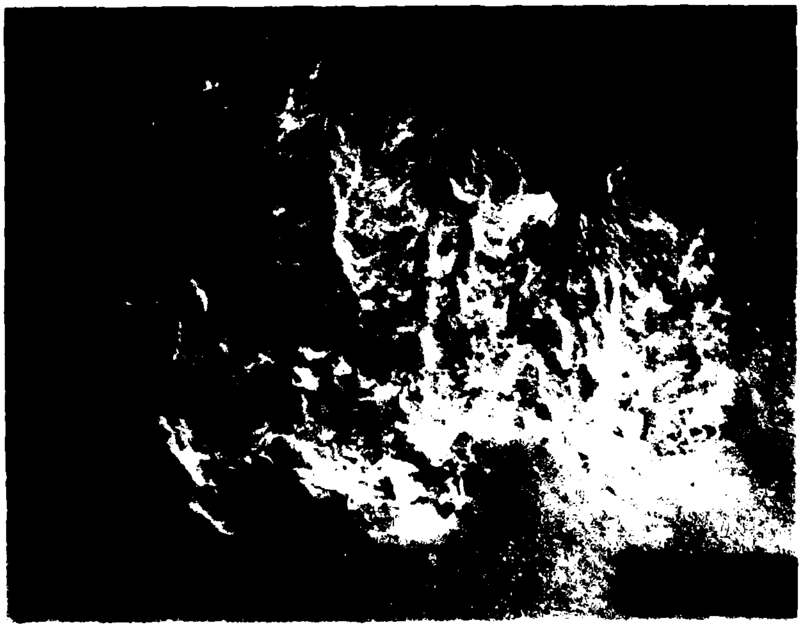


FIG. 4: DAMAGE TO RACE, BEARING "A"

FIG. 5: TYPICAL DAMAGE TO BALL SURFACE, BEARING "B"

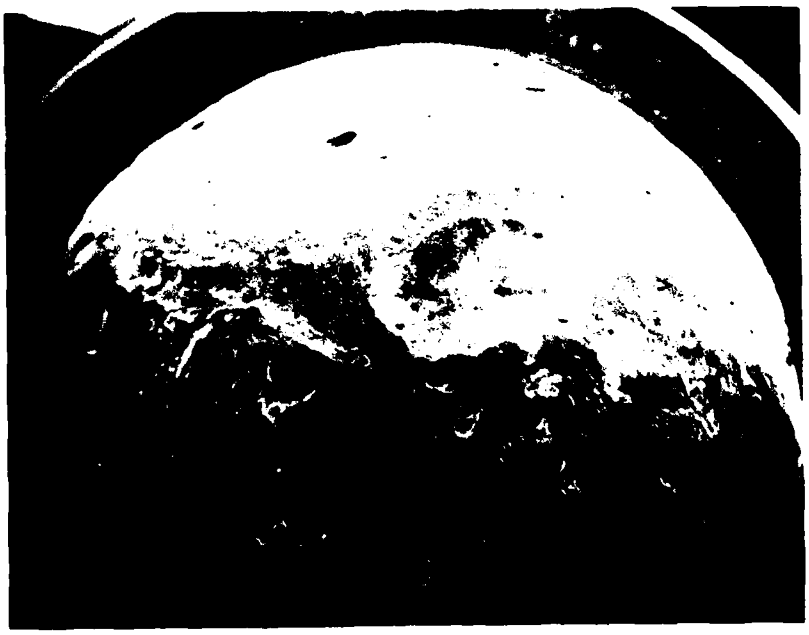


FIG. 6: CRATERS OR POOLS ON BALL SURFACE, BEARING "B"

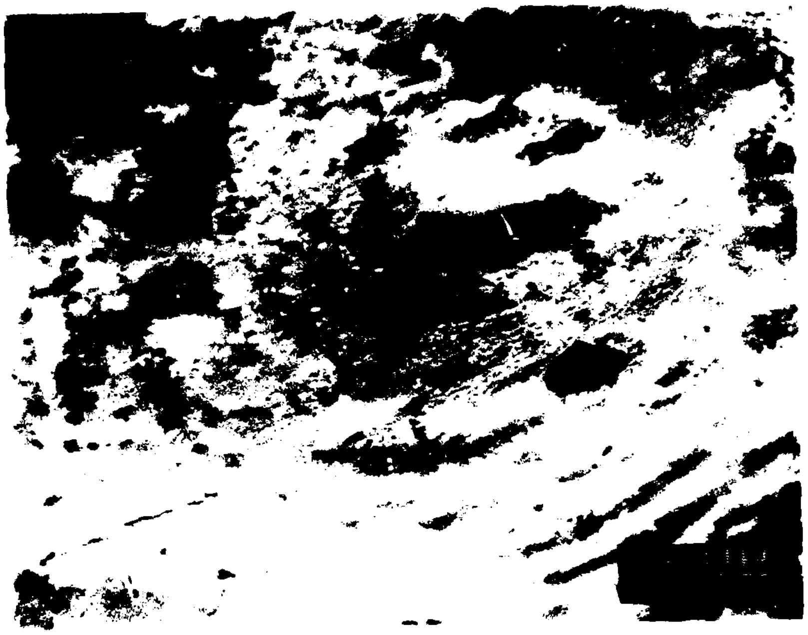


FIG. 7: RIPPLES ON POOL, BALL SURFACE, BEARING "B"

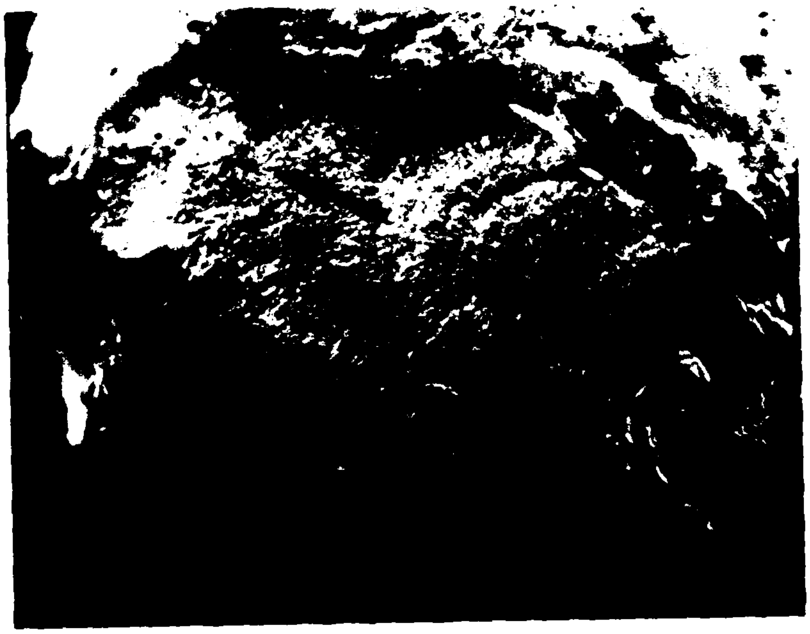
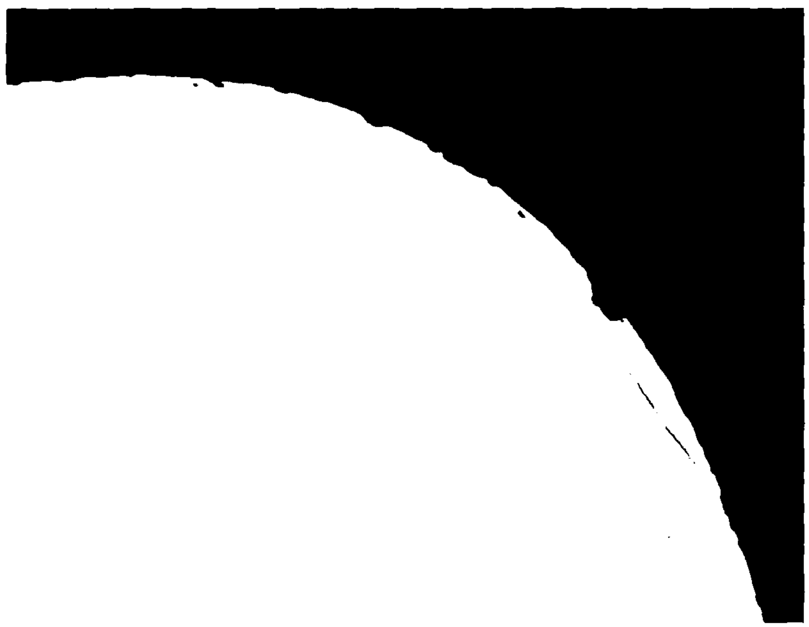


FIG. 8: LOW CYCLE FATIGUE FRACTURE ON BALL SURFACE, BEARING "B"

FIG. 9: CIRCUMFERENTIAL RACE DAMAGE, BEARING "B"

FIG. 10: RACE DAMAGE, BEARING "B"



X 20

FIG. 11: SUB-SURFACE CRACKING ON BALL FROM BEARING "B"

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SUMMARY/SOMMAIRE

Failure of a cam clutch after some 2,000 hours of operation was found to be due to bearing failure. When examined in the scanning electron microscope, evidence of molten metal in the form of craters or pools, and of minute globules of metal was found on the balls and races of the bearings. This suggested that electrical arcing between the balls and the races had occurred, and this was considered to be the primary cause of subsequent fatigue and other mechanical damage to these components.

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